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Simple and Enhanced Gain Dielectric Resonator Antenna for Ku band Application

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Abstract— A simple and compact high gain Dielectric Resonator Antenna (DRA) for Ku band frequency operation is proposed in this paper. Ku band is a microwave band having frequency range 12 to 18 GHz. Proposed DRA is based on the principal of the dual resonance and defected ground structure (DGS) having rectangular slot. DRA design resonates at frequency 15.2 GHz and 18 GHz in Ku band frequency operation. Antenna design offers the minimum return loss of -25 db at 15.2 GHz and -20 db at 18 GHz .This DRA design has simple geometry and shows good directivity that is 10 dbi at 15.2 GHz and 8 dbi at frequency 18 GHz. DRA antenna design also offers high front to back ratio (FBR) of 12.2 db and 7 db at 15.2 GHz and 18 GHz respectively. Proposed antenna design is useful at high directivity application such as satellite communication. Return loss bandwidth achieved is 540 MHz (3 %) for band resonating at 15.2 GHz and 740 MHz (4.2%) for another band resonating at 18 GHz. Simple and compact design with enhanced directivity and FBR is proposed here. DRA is analyzed using Ansoft HFSS based on finite element method.

Index Terms — Dielectric resonator antenna, dual resonance, front to back ratio, Ku band.

1 Introduction

In recent years the miniaturization of antenna has received much attention in various applications such as wireless portable devices, which encouraged the antenna engineers to design compact size antennas. Also micro strip antenna at Ku band for satellite communication and radar application usually offers high metallic loss. The DRA can be a good choice for these requirements as it overcomes the problem of high losses due to the absence of metal. DRA generally made up of dielectric materials of high dielectric constants (10-100) for microwave applications. It is a volumetric radiator and has larger aperture area than micro strip antenna and gives high radiation efficiency.

Dielectric resonator antennas (DRAs) have many advantages over micro-strip patch antennas such as small size, high radiation efficiency, wide bandwidth, and absence of surface waves [1],[2],[3],[4].DRAs of various shapes such as cylindrical, hemispherical, rectangular, and ring have been presented in the literature [3,5,10,18,20]. The rectangular-shaped DRAs offer advantages over cylindrical and hemispherical as they are easier to fabricate and have more design flexibility [3],[7].

Wireless satellite communication systems and radars require low profile compact antennas with high gain and wide bandwidth. The rectangular DRA can be designed as a compact and low profile antenna [7]. However, it suffers from low gain. Many efforts have been made to enhance the gain of the DRA. They include using an offset dual-disk dielectric resonator (DR), stacking parasitic DR[11,16], and using composite layered DR of high permittivity [1},[2],[4,[5],[6].These efforts resulted in the gain improvements of up to 2.7dB over a single DRA element. The quasi-planar surface mounted horn with an aperture coupled patch antenna has been investigated for enhanced gain [6]. The surface mounted horn shows impedance bandwidth of 3.6% and a maximum gain of 8.9 dB (neglecting metal losses) at 6.0 GHz. Thus the surface mounted horn considerably improves gain of the DRA. However, above designs are large and hence not suitable for low profile antenna applications.

This paper presents a simple dielectric resonator antenna with DGS (defected ground structure) having rectangular slot, that operates at the Ku- band microwave operation. In the proposed method ground plane with rectangular slot (DGS) is used above the substrate and feed line is used beneath the substrate that enhances the coupling of the energy to DRA and enhances the gain. The proposed antenna is simulated using FEM based HFSS simulator and the return loss, VSWR, radiation patterns and FBR are observed.

2 Antenna Geometry

DRA design has a substrate of dimension 4.5 cm x 4.5 cm x 0.14 cm. FR4 epoxy having dielectric constant 4.4 is used here. DRA is chosen of rectangular shape with dimension 1cm x 2 cm x 0.5 cm. Dielectric material with high dielectric constant is used. High dielectric constant material improves coupling and reduces the size but also lowers BW. In this design dielectric constant 10 is used. Slot is introduced in the ground plane with dimension ls 0.31cm (length of slot), Ws 0.062 cm (width of slot), lstub 0.549(stub length). Feed line is used with length 2.9 cm and width 0.06 cm. The 3 D view of design is shown below. The basic element of DGS is a resonant gap or slot in the ground DRA surface shown in fig (1).

Although no any design formula are accurately given and the hit & trial method is used to enhance the performance. However approximate modeling DRA has been done using following mathematical relations that gives the approximate idea for designing of the DRA [26].

The DRA size (length, width & height) of the DRA can be approximated by the relation given below such that (l > w > h):

$$DRA_{size} \propto \frac{\lambda_o}{\sqrt{\varepsilon_r}} \qquad (1)$$

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The Substrate thickness of antenna is given as,

$$h_s = \frac{0.3c}{2\pi f\sqrt{\varepsilon_s}} \qquad (2)$$

Total height of the DRA can be calculated by,

$$h_t = h_{dra} + h_s \qquad (3)$$

where,

$$\mathrm{h}_{dra} = \frac{\lambda_0}{4\sqrt{\varepsilon_{dra}}}$$

The stub length can be given as,

$$l_{stub} = \frac{\lambda_g}{4} \qquad (4)$$

The guide wavelength of the DRA is given as,

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{reff}}} \qquad (5)$$

The slot dimensions are approximated as,

$$w_s \approx 0.2 l_s \qquad (6)$$

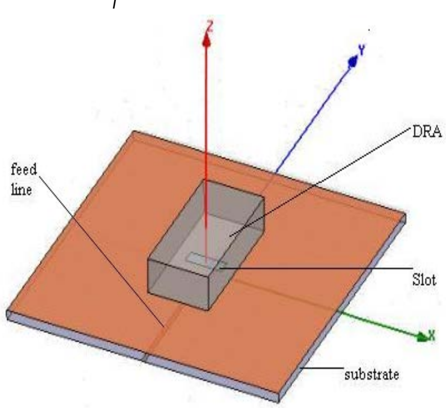
$$l_s \approx \frac{0.4\lambda_0}{\varepsilon_{reff}} \qquad (7)$$

The effective dielectric constant of the DRA is given as,

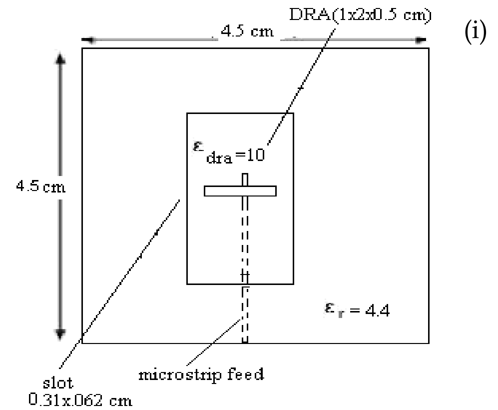
$$\varepsilon_{reff} = \frac{h_t}{\frac{h_{dra}}{\varepsilon_{dra}} + \frac{h_s}{\varepsilon_s}} \qquad (8)$$

The feed line dimension can be approximated by

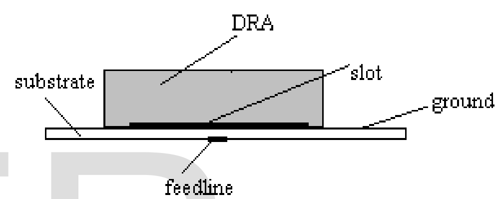
$$\frac{L_f}{W_f} \approx 3.96 \qquad (9)$$



(i)



(ii)

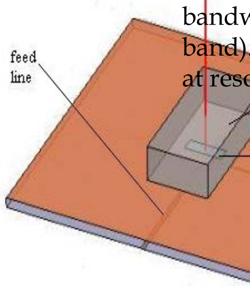


(iii)

Figure 1.Rectangular DRA (i) HFSS view (ii) Top view (iii) Front view

3 Results and Discussion

This section shows the simulated results observed using FEM based software HFSS 11.Figure 2 gives the reflection coefficients of the proposed DRA. We can notice that for the DRA dual frequency bands are obtained with impedance matching bandwidth of 540 MHz (I band) and 740 MHz (II band).Minimum return loss of 24.5 db and 19.8 db is obtained at resonant frequencies 15.2 GHz and 18 GHz respectively.



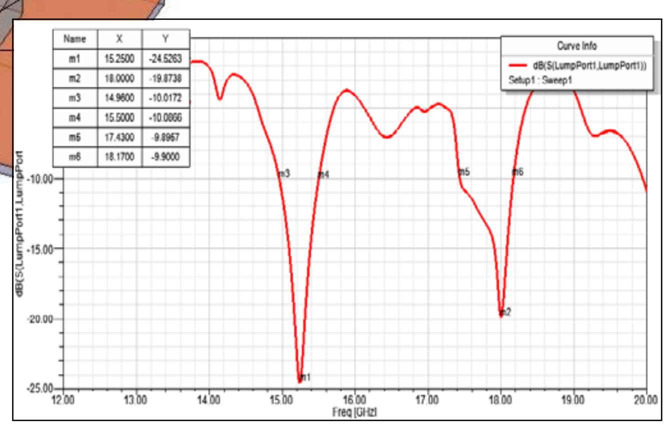


Figure 2: Return loss Vs frequency plot

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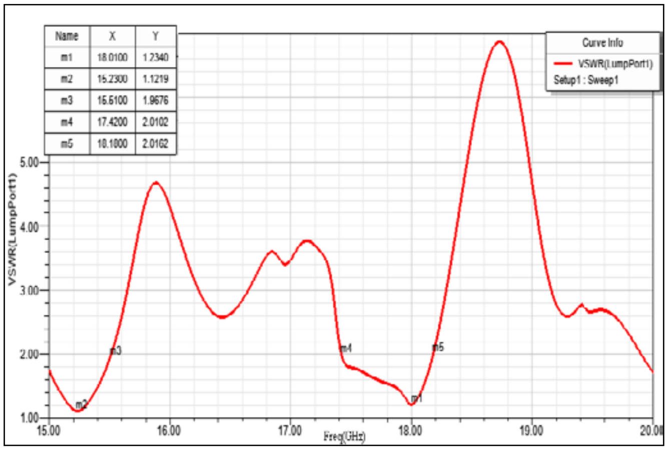

Figure 3: VSWR vs. frequency plot

Figure 3 shows the simulated VSWR of the proposed antenna. It is clearly shown that the VSWR is less than 2 for the matching frequency band.

Table 1

Proposed DRA (Dual band)	Freq band (GHz)	Resonant Freq (GHz)	Min Return Loss(db)	BW (MHz)	BW %
Band 1	14.96-15.5	15.2	-24.5	540	3%
Band 2	17.43-18.17	18	-19.8	740	4.2 %

Table 1 given above shows the performance of the Proposed DRA such as bandwidth and minimum return loss.Figure 4 & 5 represent the directivity patterns of the proposed antenna at 15.2 GHz and 18 GHz respectively. It is observed from the radiation patterns that high front to back ratio (FBR) of 12.2 db and directivity of 10 dbi at 15.2 GHz is achieved. Also FBR of 7 db and directivity 8 dbi is observed at 18 GHz resonant frequency.

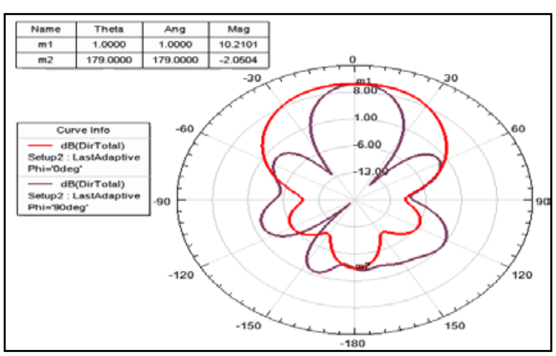

Figure 4 Simulated directivity patterns of the proposed antenna at 15.2 GHz

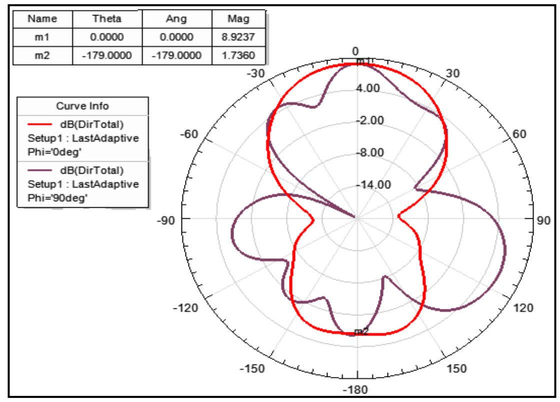

Figure 5. Simulated directivity patterns of the proposed antenna at 18 GHz

Table 2

Proposed DRA (Dual band)	Freq (GHz)	Directivity (dbi)	FBR (db)
Band 1	15.2	10	12.2
Band 2	18	8	7

Table 2 summarizes the directivity and FBR (front to back ratio) of the proposed DRA for resonant frequencies 15.2 GHz and 18 GHz.

The 3 D radiation pattern of it is shown in figure 6. The smith chart is showing the impedance matching of DRA with micro strip feed in figure 7. The larger loops on the smith chart ensure good input impedance matching over a larger range of frequencies and also tune the antenna. So loop passing much closed to 1 signifies proper matching between antenna impedance and feed impedance.

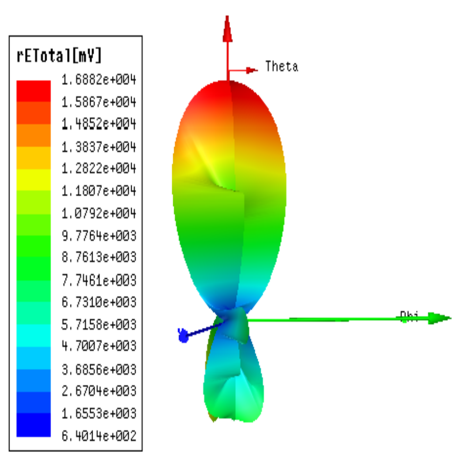

Figure6: 3DRadiation Pattern plot

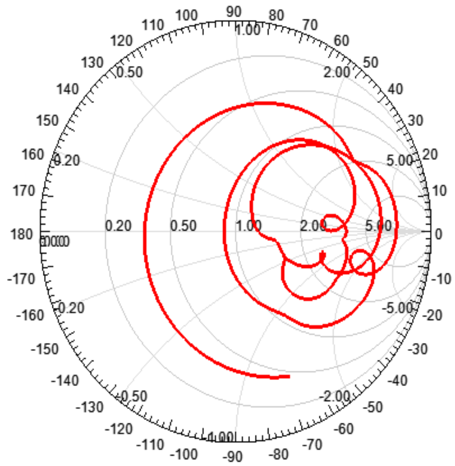

Figure 7: Smith Chart

4 Conclusion

A simple and compact dual band dielectric resonator antenna for Ku band operation has been proposed in this paper. The concept of DGS (Defected Ground Structure) and dual resonance has been used to improve the performance of the DRA. The directivities achieved are 10 dbi at 15.2 GHz and 8 dbi at 18 GHz. The Proposed DRA can be used for Ku band applications as it gives improved directivity and high FBR. The main features of the proposed DRA are that it is easy to fabricate due to its simple geometry, easily used with wireless portable devices due to its small size, useful in satellite communication because of its high directivity and FBR. The limitation of the proposed DRA is its low bandwidth that can be further improved by using the bandwidth enhancement techniques to get additional advantage.

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